

during the initial start-up operation when the temperature of the water-gas shift reactor operating at the lower temperature is less than the boiling point of the water in said multiple heat source boiler of claim 1.

28. The multi heat source boiler of claim 1 wherein said boiler has multiple means of simultaneously receiving heat to generate steam from boiler feed water.

29. The boiler of claim 28 wherein one of the means of receiving heat is combustion gas mixture emanating from the double pipe heat exchanger of claim 18.

30. The boiler of claim 28 wherein one of the means of receiving heat is the process gas mixture emanating from the water-gas shift catalyst bed operated at lower temperature of claim 20.

31. The boiler of claim 28 wherein one of the means of receiving heat is water-vapor mixture emanating from the multi-functional heat exchanger of claim 23.

32. The fuel processor of claim 1, wherein said single vessel water exchanged multi-staged preferential oxidation reactor is comprised of multiple stages and each stage is comprised of parallel tubular reactors filled with fixed beds of preferential oxidation catalyst, means of adding air to each fixed bed of catalyst, and means of maintaining the appropriate reactor temperature including means of removing the exothermic heat of the preferential oxidation reaction, all being arranged in a shell and tube geometries.

33. The preferential oxidation reactor of claim 32 wherein at least two stages of fixed beds of catalyst are used.

34. The preferential oxidation reactor of claim 33 wherein the total amount of air is divided among the two stages in a proportion having a range from 90:10 to 30:70 and preferably from 80:20 to 40:60, where the first figure is the proportion that enters the first fixed bed and the second figure is the proportion that enters the second fixed bed.

35. The preferential oxidation reactor of claim 32 wherein said means of maintaining the temperature of said reactor is a stream of water that is at the appropriate temperature.

36. The preferential oxidation reactor of claim 35 wherein said stream of water is obtained by a means of integrating the fuel processor with the fuel cell stack, more particularly it is the cooling water from a fuel cell stack that has been integrated with the fuel processing apparatus of claim 1.

37. The preferential oxidation reactor of claim 32 wherein said stream of water is passed over the shell side of the tubular reactors within the various stages of said preferential oxidation reactor.

38. The preferential oxidation reactor of claim 36 wherein said water stream exchanges heat initially with the first stage tubular reactors having fixed beds of catalyst and later with the last stage of tubular reactors having fixed beds of catalyst.

39. The preferential oxidation reactor of claim 36 wherein said water stream exchanges heat initially with the last stage of tubular reactors having fixed beds of catalyst and later with the first stage of tubular reactors having fixed beds of catalyst.

Abstract

A fuel processor including a hydrogen generating apparatus, a single vessel heat-integrated multi-stage water-gas shift reactor, a multifunctional heat exchanger, a

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multiple heat source boiler, and a single vessel water exchanged multi-staged preferential oxidation reactor is integrated with a fuel cell stack. Hydrogen is manufactured by the fuel processing apparatus and is consumed by the fuel cell stack, thereby providing one means of integration. The portion of the hydrogen that is not utilized within the fuel cell stack is subsequently burned in the combustion chamber of the fuel processing apparatus thereby providing a second means of integration. The warm cooling water that exits from the fuel cell stack is used as a heat sink for the exothermic heat of reaction in the preferential oxidation reactor, thereby providing a third means of integration.

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